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NEW ADVANCES IN SMART PACKAGING PRODUCTION METHODS

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ABSTRACT

The Consumer wants and demands longer life expectancy in food and beverage to adapt to the changing global trends. Food packing technology is used to pack the food to maintain quality and avoid contamination. The food business has seen significant advancements in the packaging sector, with the majority of active and intelligent improvements occurring in food manufacturing, and packaging innovation. Active and intelligent packaging is a new and fascinating area of technology that has a positive impact on today's consumer needs. Active packaging technology is used for producing high-quality food products with safer packing techniques. This will support the food to endure the environment and expand its lifetime. Whereas an intelligent packing system uses sensors, indicators & other carriers which are used to monitor the product condition and its current state during transit. This article presents a quick analysis of the food-packing technologies that are widely implemented.
Keywords: Smart Package, Active Package, Intelligent Package, Sensors, bio-polymers,

1 INTRODUCTION

Intelligent packaging is a technology in its infant stage of progress that influences the packaging industry to aid in decision-making to gain assistance on improved food safety and quality. Indicators like temperatures carbon oxide, oxygen and moisture are used to give information about the temperature of the packaged item, oxidative enzymes, carbon dioxide content in product packaging and products shelf life respectively [1]. Other than basic indicators, pathogen indicator provides information on the microbiological state of meat, poultry, or fish packing, Freshness indicator responds to the metabolites generated by microbe growth which reflects the microbiological quality of the product Wireless data-collecting technology makes use of electronic tags (RFID) to store data and identify animals, objects, or people (Fig.1). Tags transfer data to the reader that are connected to the product. An intelligent sensor emits a signal in response to the detection of a chemical or physical characteristic. These intelligent devices have two functional systems, initially, a receptor which generates energy from chemical or physical and then a transducer, which generates an analytical signal from energy received from the receptor. The analytical signal from the transducer is used to depict the product status. Gas sensors are devices used to react to the predicted and selectively to the presence of gases to intimate the changes happening the food storage environment [1,2].

Fig. 1 Illustration of Intelligent Packing

In the olden days, the packed food materials were in contact with the package wrapper which reduces the food life span & it is not suitable to carry food for a long distance with varying environments. But nowadays, with the improved technology in the field of packing techniques with non–porous, air-tight, non – biodegradable wrappers are used to avoid environmental contact, improve protection & enhance the life span of the diet items [3]. In the present scenario, active and the Intelligent packaging are the two types of manufacturing systems that are widely implemented [4]. The active packaging system

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establishes direct contact with the food products to know more information and improves the product storage life. Whereas RFID tags in the intelligent packaging system provide the product information, its conditions etc. The major difference between these two packaging systems is the contact with the food for monitoring conditions, but these two are the constituents of smart packaging systems (Fig.2).

The major concern of packaging is to improve the shelf life, and food value retention and not only just wrapping the product. In the process of addressing above mentioned objectives, most of the food industries are venturing into smart packaging [5]. In smart packaging, there will be sensors, labels, and indicators, in the food packaging to provide the function of contaminant, precaution, and communication facilities of new generation packaging the basic function is of production, transportation is our main motive is to replace the active packaging is smart packaging.

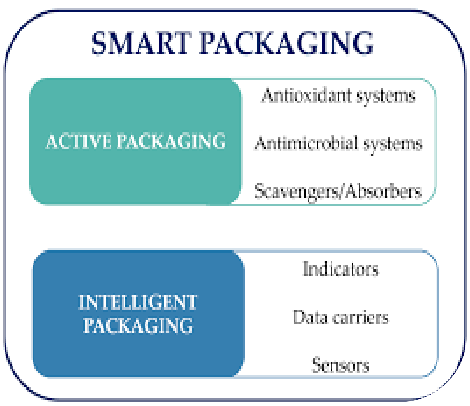

Fig. 2 Illustration of Intelligent Packing

In active packaging, the package interacts with the food via covering surfaces, either way, to emit or absorb substances into or from the packed food or the surroundings. In some instances, innovative packaging concepts may also be found in active packaging. Another important scope of the active package system is the active scavenging. That may be because absorbers and active releasing systems acts like emitters in the active package system. In that, absorber removes unwanted components from the food or its surroundings, such as moisture, carbon dioxide, oxygen, ethylene, or aroma, whereas the emitters add antioxidants, antimicrobial compounds, flavours, carbon dioxide, ethylene, or ethanol to the packed food (Fig.3)[6].

Fig. 3 Agents used in Active Food Packing

Intelligent food packing technology is the recent technology to expand shelf-life quality, safety, and security of food items. There are some disadvantages to this intelligent system because of the addition of some preservatives and antioxidants in long-distance transit food materials [7]. Understanding the importance of smart packing and its need in the current scenario, the following section describes the methods and materials used in advanced smart packing.

2. METHODOLOGY

2.1 Cassava Starch and Anthocyanins package films in Active and Intelligent Packing.

Lycium Ruthenium Murr consists of abundant anthocyanins and it is a functional food for the Micro-organisms [8]. The sensitive packing film can be developed using Cassava starch and Anthocyanins by pH. The anthocyanins colour changes with pH attributed to the physical, structural and antioxidant contents of LRA (Lycium Ruthenium Anthocyanins). Such LRA films are widely preferred to monitor Pork freshness. Incorporating LRA in the packaging film enhances the property of water vapour, UV light barrier capacity, antioxidant potential and tensile strength, whereas it has no effect on thermal stability. Such a pH-sensitive LRA films behave differently in buffer solution exhibiting colour change.

The rising awareness of food safety and a litter-free environment among people has given more attention to developing safe and recyclable food packaging films. To address such requirements naturally available biopolymers such as proteins, lipids, and polysaccharides are frequently used as a food-covering matrix. In that film, starch has received a lot of attention among biopolymers because it is biodegradable, edible, economic and plenty. The amyloprotein and amylose are the elements present in semicrystalline granules of native starch. Amylose is a linear polymer composed of glucopy-linked glucopyranose units. Whereas, Amyloprotein is a highly branched polymer with a (1,4)-glycosidic bond connected by a – (1,6)-glycosidic bond. The cultivation origin has its own influence on the composition, structure and functions of the starch which are sorted accordingly for commercial use. The functional food of the genus Lycium is Lycium ruthenium Murr and the abundance of anthocyanins in Solanaceae. L. ruthenium contributes to have numerous therapeutic effects. Furthermore, the spectroscopic technique classifies anthocyanins into six different kinds. Food packaging films for both active and intelligent system has been developed using Cassava starch by adding different levels of LRA in the starch matrix. Along with passive packaging films, smart packaging films are used with sensors to improve the shelf life of products. These smart films are active systems which are used to keep track of food freshness.

2.2 pH-sensitive films as food deterioration indicator.

Consumers can benefit from improved preservation and convenience thanks to intelligent packaging. In most of the discussions, polyvinyl alcohol (PVA) and Corn starch films are widely considered as film materials [9]. Purple sweet potato extracts (PSPE) and red cabbage extracts (RCE) were used to examine the easily accessible anthocyanin sources and their ability to indicate the freshness of food. The observed colour differences were visible in films containing PSPE or RCE alterations in various buffers. An increase of RCE or lesser levels of PSPE had no effect on water vapour permeability (WVP) (pN 0.05). On increasing PSPE or RCE, from 64.0 to 97.7 or 85.5 m, respectively, the mechanical tensile strength increases from 7.3 to 9.1 or 11.3 MPa i.e, in the range of 24 to 54 per cent.

Concerns about environmental responsibilities related to the large-scale waste of non-biodegradable plastics and the depletion of oil supply sources are the driving attempts to explore and examine degradable and renewable materials. Among the biopolymer materials available, particularly maize starch is ample, low-cost, decomposable, edible, and has the ability to form strong film, which is all making it as one of the most promising plastic substitutes. The Starch-based films provide a wide range of mechanical characteristics and it is strengthened further by blending with other recyclable polymers. In that category, Polyvinyl alcohol (PVA) is one of the better add-ons for the creation of films and coatings. Aside from the sustainability of food packaging, correct shelf-life information is another key issue that must be addressed. Products whose remaining shelf life cannot be determined uses intelligent packaging, particularly pH-sensitive packaging, has attracted a lot of attention. Few studies, however, have compared anthocyanins from various sources, including in certain circumstances, even the food model part. The goal of the work is to present the application of Starch/PVA polymer matrix as pH-sensitive films as well as to compare the films that are having anthocyanins from different sources. Food-grade sources are cheap and easily available. Furthermore, such food grade films were used in the packaging to monitor the deteriorating process of refrigerated shrimp.

PVA and starch were effectively combined with varying amounts of PSPE or RCE to create a pH-sensitive film. When exposed to different pH buffers, both PSPSPE and PS-RCE films showed distinct hues. After adding RCE or a reduced amount of PSPE, the WVP of the films did not change significantly (pN 0.05). Due to the existence of PSPE or RCE, the film thickness, mechanical, and thermal properties were significantly improved with a drop in the light transmittance [10]. Because of the varied compositions and contents of anthocyanins, the PS-PSPE film exhibit notable colour, superior mechanical capabilities, and lower light transmission than PS-RCE film. Thus the PS-PSPE film was chosen as a better candidate for film packaging because of its high anthocyanin content and outstanding physical characteristics.

2.3 Brassica oleracea extract and Chitosan/corn starch blend films as a visual indicator

PVA and starch were effectively combined with varying amounts of PSPE or RCE to create a pH-sensitive film. When exposed with different pH buffers, both PSPSPE and PS-RCE films showed distinct changes.

After adding RCE or a reduced amount of PSPE, the WVP of the films did not change significantly (pN 0.05). Because of the varied compositions and contents of anthocyanins, PS-PSPE film had a more remarkable colour with higher mechanical capabilities, and lower light transmission than PS-RCE film at a lower extract amount. The PS-PSPE film was chosen because of its high anthocyanin content and outstanding physical characteristics. The film-forming characteristics of and Starch and Chitosan are decomposable polymers with good film-forming characteristics and have varied applications [11]. The food industry product requires the most striking protection with an antioxidant coating, as well as shelf-life extensions, which are achieved by active and intelligent packaging films. The intelligent packages which keep track of the real time food's status should be simple, sensitive, and efficient in order to securely specify the food quality to the buyer. However, the food decomposition in many food products are indicated by the pH Changes as a visual signal to the buyer[12].

As a result, the pH changes in the food are visually detected and monitored by the pH indicator in the intelligent packaging system. Fish is one of the most popular foods on the planet, and it's particularly susceptible to bacterial deterioration, which causes an elevation in the pH of the fish owing to higher quantities of unstable nitrogen. As a result, system comprises of chitosan, corn starch, and red cabbage extract has been effectively used as a natural pH indicator for monitoring fish pH. According to the findings of this study, renewable resources based very sensitive visual pH indicator film based has been produced. Additionally, the film components are highly inactive with other components and such blends are thermally stable. The indicator film responds well to pH variations, allowing it to detect pH changes safely and hence it is utilized as a visual indicator of food spoilage. The stability of starch extract, film response at various temperatures, and film's mechanical properties are all important points focused on the future.

2.4 Smart Manufacturing with Information flow-based matching service

The future movement of the factories are the interconnection of the ideas among the machines & production system for enhanced operational autonomy. Such an interconnected information flow was made possible by the implementation of the theory of information flow (IF). It is a network theory, based on a matching framework to define the capability of matching services[13]. The complications which arise due to different production steps are minimised by uniting the production capabilities of equipment and tooling. This sort of brings together the production steps & production equipment is done by the theory of information flow (IF). The IF is a network theory which supports the mathematical tool to express the stream of data within the concerned system. The I.F theory creates math models for the individual components and the types are represented in the form of classification paragraphs.

Channel theory info-morphisms:

In channel theory, information can be carried interchanged between the components to tune the information and classifications.

The literature disseminates a novel approach to design the components as per IF theory suitable for the application domain. Whereas, it cannot endure with the increased complicity in smart manufacturing and hence enhancing the traditional way of IF application is much needed for the present scenario.

2.5 Smart packing- opportunities & challenges:

Smart packing refers to a packing system with implanted sensor technology in the packaging of foods, medicines and many other types of products. The implanted sensors are used to monitor food freshness, display manufacturers' information, shelf-life, quality and in some instances improve product safety [1,14]. The main functions of the product packing system are product information, manufacturer and accessibility. The purpose of product packing is to :

- Prevent leaking or breaking of product due to external actions/factors.
- Contact information, nutritive content of the product and culinary details.
- Support reheating the food in varies heating sources like microwave etc.
- Support ease of transportation.

2.6 Underlying technologies of packaging system:

The technologies used in the package system are of three types as follows which are applied in wide area of market for potential product to improve products performance.

- Active packaging
- Intelligent packaging
- Smart packaging

Active packaging:

Includes presence of scavengers to eliminate gases like oxygen, ethylene etc, odour absorber/ releases, antimicrobial & antioxidants and preserve food flavours.

Intelligent packaging:

Commonly uses biosensors to monitor the status of the packaged foods, detect, record and transmit information and tracking freshness levels.

Smart Packaging:

Smart packaging uses variety of sensors including biosensor to monitor and analyse the freshness, pathogens, leakages, carbon dioxide, pH level, time and temperature conditions suitable for the product quality. The package industry has wide scope in global market for advanced packaging system with a level of $ 31.4 billion in 2011 & $ 33.3 billion in 2012, respectively. Such universal demand for electronic smart packing is anticipated to raise to over few $100 billion in the next decade.

2.7. Sensor & Actuators B channel

Tetra phenylethylane functionalized polyaniline (PANI) based dual mode smart package sensor is devised for fish freshness monitoring. The stimuli-responsive polymer polyaniline (PANI) and the aggregation property of tetra phenylethylane (PPE) has been the source for making of novel colorimetric and fluorescent dual mode sensing label [15] . Such sensors in the smart packing technology is proficient enough to recognize the goodness of the package.

Thus, the twin mode sensing label are used as an on package of highly delicate products like fish to ensure their quality during purchase [16]. A study on hybrid sensing labels, the AIE property of TPE dye and stimulus of PANI are combined to monitor the freshness of fish. Such types of sensing label show both the colorimetric variation and luminous "Turn on" response on the release of basic amines from the food sample. During fish decay, some basic metabolic volatiles such as trimethylamine, and ammonia are produced in the fish samples [17]. The generated TPE get trapped in the PANI structure exhibiting considerable contrast among PANI and PANI/TPE. The contrast variation was characterized by Fluorescence spectroscopy as ratio of TPE to TPE/PANI. The sensing label formed by PANI/TPE shows observable colour changes in the image of food on spoiling which was clearer than visible colour variations in natural light.

Hence it is seen, a dual-mode was successfully developed via detection label for the quick, subtle and non-destructive monitoring of the seafood goodness of The extraction of ΔE data from sensing labels could support the retailers to compute the TVB – iv amount to quantitively evaluate the freshness of animal food.

2.8. **Anthocyanin**

Sustenance of smart packing relies on the production and use of Cassava starch and Anthocyanin (ATH)[18,19]. The packaging material for smart packing from Cassava Starch and a Natural pH Indicator Anthocyanin is most often manufactured by Turn Screw Extrusion Process. This kind of packing enables smart packing to improve food safety and quality characteristics as in the case of Fresh Food material, High Protein Food, Fish and Meat, Highly perishable Goods Etc. Anthocyanin is a pH-sensitive Phenotic Family which are responsible for colours in plants, a non-toxic and safe alternative dye for packing application[15], [20]. The varying concentration of ATH (5, 10, 20 mg) per 100g on the selected sheet act as an indicator of pH Changes. The Incorporation of ATH-generated sheets (2.5x) thicker are less resistant at break (4.5x), less elastic (-1.4x) and less rigid (-4.5x). However, the ATH does not affect the crystallinity profile. The addition of 20mg ATH in 100g thermoplastic starch sheets presented the best behaviour as a smart indicator of pH change, which has been used to monitor stored meat at 6'C with notable changes in energy and colour. Thus the addition of anthocyanin in sheet actives the mechanical properties and can be well implemented to make the smart sheet in mass production.

2.9 **Carbohydrates Polymers**

In a daily basis plastics are used to cover food products and which may lead to carcinogenic diseases. To address this issue scientists are developing biodegradable film made of milk protein. It is environmentally friendly and will not produce pollution.

2.9.1 Starch Based polymer:

Biodegradable starch-based plastic, where starch is a polymeric carbohydrate with several thousand units of glucose arranged in the linear chain known as amylose or in branched structure (known as amylopectin). However, pure starch-based bio-plastic may be brittle. The thermophysical processing of plasticizers such as sorbitol, glycerol and glycol results in bioplastic thermoplastic starch. The addition of special additives to such thermoplastic starch can tailor to the film to specific applications.

Often Starch-based films (mostly used for packaging purposes) are made by blending thermoplastic polyesters with starch blended to form biodegradable, compostable products, goods packaging wrappers and bubble films. The mechanical properties of starch-based polymer are highly influenced by the presence of amylose to amylopectin ratio. The common processing method deployed to process starch-based polymer into bio-based plastics is extrusion, injection moulding and solution casting.

2.9.2 Chitoson hydrogel

The Chitoson is a compound derived from the fractional deacetylation of ordinary chitin with linear semi crystalline polysaccharides with disinfection, biocompatibility and thermosensitive properties suiting biomedical application [21]. The preparation of Chitoson in acetic acid atmosphere requires frequent filtration. A gradient structured chitosan hydrogel can be fabricated using sodium triphosphate by physical cross-linking process that are further modified by gelling process. The gradients composition and bioactive signals of Chitoson system have been widely applied for different applications such as protein delivery for interfacial tissue engineering. Knowing the capacity of Chitoson hydrogel, they can be used for packaging of biomedical in application like targeted drug delivery and gene delivery.

2.10 Bio-Polymers

Biopolymers prevents environmental impact from plastic or other not degradable material. The bio polymers are produced by living organism and best example for bio polymers are:

- Carbohydrates
- Protein
- Nucleic acid
- Lipid

Carbohydrates are an important source of energy in all living organisms. Mainly we see that starch plays a major role in biopolymers in the form of granules composed of two macromolecules(amylose) gathered by glycoside link and cost-effective. The usage of plastic ruins the environment and a feasible solution for this global issue is to practice the bio-based polymers material from sources like polysaccharides to replace the synthetic ones. Though it supports the environment, it has its own drawbacks such as poor acid and thermal stability. Starch-based bio-nano composites use nanofillers to improve mechanical and thermal properties.

Chitosan (CS) is a natural polysaccharide bio-nano composites that can be used for the application of drug wrapping. These types of nanocomposites are the combined mixture of nano and masterbatch pellets to get precise final nanocomposites concentrate. Usually, it is 0.5-1.0g of nano fillers per 100g of the composites film is used in twin screw extruder system to produce parts with plate die and connected calendar system. The processing of CS by extrusion process does use detrimental solvents which supports upscaling to produce material to an large-scale business. It is evident that, the films derived from a natural source such as starch and chitosan are considered as safe packaging materials to replace plastics.

3 HEAT RESISTANT AND PERMEABLE SMART PACKING SYSTEM.

This section describes the behaviour of phase change material in packing system [22]. The gas concentration inside the packed material can be effectively controlled by the phase change material by changing its gas permeability by changing temperature. The composite film with temperature depends gas permeability was prepared with porosity for desirable gas composition of products like tomatoes [7], subsequently the packaging films can extent the shelf life of products.

Generally, low temperature atmosphere is preferred to extend the shelf life of the perishable items and it is in the order of 10-15 ^{0} C for the product cherry tomatoes. There are various attempts tried to prevent or delay the deterioration effects caused by the respiratory gas of the food materials inside packing. Once such measure is prevention of thermal effects by controlling the headspace composition of wrapped products to maintain the quality of the during storage [23] . In another approach, the package is filled with modified atmospheric gas to prevent the formation of microbes and bacteria.

However, in the wrapping of cherry tomatoes three different films PP/OD/ZC were prepared using twin screw extruder. In the making of films, PP/OD are melted to liquid and mixed with ZC powder has and stirred to form a homogenous mixture, then extruded to form films. The mixture is extruded to produce films and the films used scientifically with the following three parameters for effective packaging: There are different parameters considered in heat resistant and permeable packing are:

- Head Spacing
- Rigidness
- Appearance

Head Spacing:

Head space volume can be attained by packing products of different sizes and quantity in a pouch and sealed. The volume of headspace in the package can be measured by the difference between the total volume of the pouch and volume of the product. The storage temperature and volume of package products affects the atmosphere in the headspace of the package as well as gas and water vapour permeability of the packaging material. Thus, the headspace gas of packaged products is used to predict the shelf life.

Rigidness:

The rigidness of the product before packing is one of the parameters to ensure good quality to the consumer. Generally, it can be measured by simple compression test using 3mm diameter cylindrical probe. The maximum compressive force that punctures is the rigidness of the product.

Appearance:

Colour is the parameter which depicts the product's appearance which can be measured by light spectroscopy or visual inspection. Such an evaluation was carried out on each product and analysed in different zones to detect the colour changes caused by ripening during storage.

4 CONCLUSIONS

We have witnessed that the two types of packaging systems are efficiently used in society to avoid environmental contamination & to increase life span. This study gives quick information about the packaging system by various manufacturing techniques with biocompatible materials to overcome the challenges in society and successful development of the food industry with commercial function.

With a sophisticated active packaging system, the product quality will be retained, and infections bacteria will not proliferate. That can be achieved based on the product's attributes, preferred conditions, and responses to stimuli. Intelligent packaging technologies are simply applied to the product's outside surface or packaging to increase product traceability and safety information the customer. Smart packaging can connect with its surroundings in the supply chain as well as with consumers. Smart devices in the form of RFID can be used to inform consumers with current and manufacturer information.

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